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Phytoplankton associated with the ice edge in the Barents Sea during the spring and summer is one of the most productive areas in the world oceans. These blooms move northward as the ice recedes, creating a belt of production at the marginal ice zone. Given the complexity of the physical environment and the extremes in solar radiation, the blooms are highly dependent on the variability associated with the environment. In particular, inter-annual variability in bloom composition and intensity is high. Few projects in the past have addressed this question. The two dominant phytoplankton taxa in the area are diatoms and the flagellate *Phaeocystis pouchetii.* Results from this project show that (1) In the Polar Front / Atlantic Waters, *Phaeocystis* sp. blooms were distributed in waters with high concentrations of silicic acid and diatoms were found at all nutrient levels but in particular at lower levels of silicic acid; (2) In Arctic Waters, diatoms were found in waters that had high silicic acid and nitrate while *Phaeocystis* sp. was found in waters with very low silicic acid but still with some nitrate. Thus, these results show that water masses have an influence on which species blooms first, a new insight for this area.

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Final report on "ProMare Time Series in the Barents Sea: Control of Ice-edge Blooms by Environmental Variables"
Grant Number N00014-94-1-1045
PI: Maria Vernet, Scripps Institution of Oceanography

**Abstract**

Phytoplankton associated with the ice edge in the Barents Sea during the spring and summer is one of the most productive areas in the world oceans. These blooms move northward as the ice recedes, creating a belt of production at the marginal ice zone. Given the complexity of the physical environment and the extremes in solar radiation, the blooms are highly dependent on the variability associated with the environment. In particular, inter-annual variability in bloom composition and intensity is high. Few projects in the past have addressed this question. The two dominant phytoplankton taxa in the area are diatoms and the flagellate *Phaeocystis pouchetii*. Results from this project show that (1) In the Polar Front / Atlantic Waters, *Phaeocystis* sp. blooms were distributed in waters with high concentrations of silicic acid and diatoms were found at all nutrient levels but in particular at lower levels of silicic acid; (2) In Arctic Waters, diatoms were found in waters that had high silicic acid and nitrate while *Phaeocystis* sp. was found in waters with very low silicic acid but still with some nitrate. Thus, these results show that water masses have an influence on which species blooms first, a new insight for this area.

**Introduction**

Phytoplankton associated with the ice edge in the Arctic during the spring and summer is one of the most productive areas in the world oceans. These blooms move northward as the ice recedes during the summer, creating a belt of production at the marginal ice zone. Given the complexity of the physical environment (ocean-atmosphere-ice interactions) and the extremes in solar radiation and temperature, the blooms are highly dependent on the variability associated with the environment. In particular, inter-annual variability is high. In spite of this recognized factor, few projects in the past have addressed this question of inter-annual variability, due mainly to logistics constraints. My long-term objectives are to investigate this variability by participating on quarterly cruises to the Barents Sea sampling on a transect from Vardo to the marginal ice zone along 31° E, in collaboration with Norwegian researchers. As a first step in addressing long-term variability in biological processes in the marginal ice zone of the Barents Sea, I proposed to analyze an existing data set from the Institute of Marine Research in Bergen. Analysis of the data could provide: (1) testable hypotheses on ecosystem functioning, (2) an extension of the time series for the 1980's, and (3) a baseline for ice-edge blooms in the Arctic as we look for long-term changes that might be attributed to global change.



A large part of the studies on primary productivity of polar areas, both physiological and ecological, have concentrated on the magnitude of total primary productivity. Taxonomic and pigment analysis of the Barents Sea phytoplankton indicate that the 2 dominant taxa in the area are diatoms and the flagellate *Phaeocystis pouchetii*. These 2 types of algae present differences in their nutrient uptake, photosynthetic properties, cell size and have important implications in the food web as *Phaeocystis pouchetii* is well known to be rejected by zooplankton as a food source,

at least during exponential growth. In its colonial stage it is too large to be ingested by small zooplankton and it is considered undesirable by many large zooplankters.

Given the high biomass of chlorophyll *a* associated to phytoplankton blooms of either diatoms and/or the prymnesiophyte *Phaeocystis pouchetii* in the marginal ice zone of the Barents Sea, the high primary production associated with the bloom (Rey et al., 1987), and the length of the bloom through the growth season (May to September) as it recedes northwards (Rey and Loeng, 1985) it is important to understand the environmental variables which contribute to the dominance of the different species in the water column.

Two hypotheses have been proposed in the literature to explain the dominance of either phytoplankton taxa:

(1) Diatoms dominate early in the bloom while *Phaeocystis* sp. grows on the excess nitrate available after silicon depletion.

(2) The dominance of the prymnesiophytes (i.e. *Phaeocystis* sp.) early in the bloom is due to adaptation to low light conditions and thus the ability to grow in deep mixed layers.

Hypothesis 1 is more widely accepted and thought of as the rule. To challenge this idea there are 'abnormal years' as expressed by Steffanson and Olafsson (1990) for the area around Iceland where silicate can be measured in the water after nitrate depletion. Several observations in the literature describe similar scenarios for the Barents Sea (Wassmann et al., 1990) and the Fram Strait (Smith et al., 1990).

**Results**

During this funding period I tested hypothesis (1). Five years of the ProMare Time series, from 1979 to 1984, were analyzed. The data included phytoplankton identification and abundance, salinity, temperature, and inorganic nutrients (nitrate, silicic acid, phosphate). The data was collected mainly during winter, spring and summer months, from January to August. Ice-edge blooms, occurred mainly occurring in the months of May and June. For those, we compared diatom- and *Phaeocystis*-dominated blooms located in similar water masses, mainly Arctic Water and Atlantic Waters.

Blooms of June 1980, 1981, and 1983 were dominated by diatoms while May 1981 and June 1982 were dominated by *Phaeocystis*. Year 1984 showed a mixture of both groups. Dinoflagellates in the area were always present but never exceed 20% of the cell counts and were not included in this analysis.

For further comparison, we identified blooms that occurred in similar water masses and plot them as a function of species dominance and silicate/nitrate concentration. Water masses were defined as in Loeng (1990): Arctic Waters ($T < 0.0^{0}$ C and S = 34.3-34.8 ‰), Atlantic

Water (T > 3.0o C and S > 35.0 ‰), Polar Front Water (T = -0.5-2.0o C and S = 34.8-35.0) and Melt Water (T > 0.0o C and S < 34.2 ‰).

H1a: *Phaeocystis* sp. bloom first in the season; diatoms grow after *Phaeocystis* sp. In this scenario, silicic acid vs NO3 plots would show *Phaeocystis* sp. growing at high silicate concentrations. Later on, both nutrients would be taken up at the same rate.

H1b: *Phaeocystis* sp. grows after diatoms have bloomed leaving no silicic acid and some nitrate in the water column. Thus *Phaeocystis* sp. blooms would be found at low NO3 concentrations and non-detectable silicic acid concentrations.

Results show that:

- In the Polar Front / Atlantic Waters, *Phaeocystis* sp. blooms were distributed in waters with high concentrations of silicic acid and diatoms were found at all nutrient levels, in particular at lower levels of silicic acid, where the relationship between the 2 nutrients was linear and intercepted zero.

- In Arctic Waters, diatoms were found in waters that had high silicic acid and nitrate while *Phaeocystis* sp. was found in waters with very low silicic acid but still with some nitrate.

These results show that, as previously described, both scenarios are found in the Barents Sea. These are not new results. What is new is that the type of bloom encountered is function of the water masses in which phytoplankton grow. For Arctic Waters, diatoms bloom first and *Phaeocystis* sp. grows at the end of the bloom after diatoms have depleted the water from silicic acid. For the ice edge over the Polar Front or over Atlantic Waters, *Phaeocystis* sp. blooms first and diatoms are mixed or follow *Phaeocystis* sp. until all nutrients are depleted. Thus, on the average, surface waters during ice edge blooms in these 2 water masses have different Si:NO3 ratios in the springtime, higher in the Polar Front and Atlantic Waters (close to 1:1) and lower in Arctic Waters (close to 0.5:1). The inflow of North Atlantic Water in the Barents Sea and Arctic Waters have similar nutrient concentration at depth (11-12 µM nitrate and 6 µM silicic acid; Harrison and Cota, 1990)

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